

SANDWICH SQUARE HONEYCOMB STRUCTURE FROM BIODEGRADABLE AND RECYCLABLE COMPOSITES

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Dedicated to abah, ibu, angah, ude & adik

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ABSTRAK

Peningkatan tahap kesedaran terhadap alam sekitar menggalakkan pembangunan komposit dari serat semulajadi, terutamanya dalam struktur sarang lebah kerana sifatnya yang ringan. Struktur sarang lebah telah digunakan secara meluas di dalam pelbagai sektor industri seperti aeroangkasa, automotif dan yang terbaru di dalam sektor industri pembuatan perabot kerana ia mampu mengurangkan berat keseluruhan produk. Walaubagaimanapun, hanya sedikit sahaja kajian yang telah dilakukan terhadap struktur ini bagi memahami kekuatannya. Selain itu, prospek mengitar semula komposit serat semula jadi kepada produk baru juga belum pernah di bincangkan dalam sebarang penyelidikan sebelumnya. Tujuan utama kajian ini adalah untuk mengkaji sifat-sifat mekanik struktur segi empat sarang lebah sandwic yang diperbuat daripada tiga jenis serat semulajadi iaitu serat kenaf, serat nenas dan serat kabung bersama gentian asid polilaktik (PLA). Dalam pada itu, kajian ini juga bertujuan untuk mengkaji tingkah laku mampatan, kesan penskalaan dan analisis unsur terhingga terhadap struktur segi empat sarang lebah sandwic. Kajian ini turut mengkaji kesan mengitar semula komposit semulajadi terhadap kekuatan serta daya penyerapan tenaga. Kajian ini dijalankan terhadap komposit semulajadi yang diperbuat daripada campuran PLA dengan tiga jenis serat iaitu serat kenaf, serat nenas dan serat kabung. Serat yang panjang telah dihancurkan kepada serat pendek bagi memastikan keseragaman sepanjang proses penghasilan komposit termasuk bahagian mengitar semula. Serat dan PLA kemudian dicampur menggunakan mesin pencampur kelompok pada suhu 180 °C sebelum dihancurkan kepada palet-palet kecil untuk proses acuan penekan bersuhu panas. Setiap serat komposit di mampatkan sehingga mencapai ketebalan 3 mm selama 5 minit pada suhu 180 ° dan tekanan sebanyak 60 tan. Kemudian struktur segi empat sarang lebah sandwic yang dihasilkan akan melalui ujian kemampatan manakala plat serat komposit akan melalui ujian tegangan. Produk akhir akan dikitar semula tanpa sebarang penambahan bahan lain serta melalui proses yang sama dan menjalani set ujian yang sama bagi mengkaji kekuatan struktur segi empat sarang lebah sandwic serta tahap penyerapan tenaga. Kekuatan tegangan pengurangan komposit dikitar semula dengan kenaf / PLA mencatatkan 36.28 MPa untuk komposit baru dan 19.72 MPa untuk komposit yang dikitar semula. Selepas proses kitar semula, kekuatan tegangan berkurang sebanyak 5 – 45 %. Nilai Poisson's ratio untuk kedua-dua specimen baru dan dikitar semula berada dalam nilai 0.2 – 0.3. Selain itu, dari segi faktor skala, nilai tekanan dan penyerapan tenaga meningkat apabila bilangan sel meningkat. Komposit kabung / PLA menunjukkan kenaikan tertinggi sebanyak 115.20% apabila bilangan slot dua kali ganda. Sementara itu, model FE dibangunkan dan dianalisis dengan menggunakan perisian ABAQUS 6.13 untuk mengesahkan keputusan eksperimen yang diperolehi. Walau bagaimanapun, apabila komposit serat semula jadi dikitar semula, komposit dikitar semula kenaf / PLA mencatatkan nilai ketegasan maksimum sebanyak 7.8 MPa dan nilai penyerapan tenaga sebanyak 720.12 J berbanding komposit nenas/ PLA dan kabung / PLA yang dikitar semula. Akhir sekali, perbandingan antara model FE dan data eksperimen menunjukkan peratusan ralat yang sedikit yakni sebanyak 10.97% disebabkan oleh ketidaksempurnaan geometri struktur segi empat sarang lebah sandwic. Kajian ini menunjukkan bahawa komposit yang dikitar semula mempunyai potensi yang besar untuk digunakan sebagai bahan gentian bagi aplikasi berbeban rendah terutamanya dalam industri pembuatan perabot.

ABSTRACT

Increasing environment concern has triggered the development of natural fibre composite, especially in a honeycomb structure due to its lightweight properties. A honeycomb structure is usually used in aerospace, automotive and recently in furniture industries as it is a good weight saving option. However, only a small number of natural fibre composites have been studied as a honeycomb structure. Besides that, the prospect of recycling the natural fibre composite into a new product has yet to be discussed in any previous research. This research aims to investigate the mechanical properties of the sandwich square honeycomb structure made out of three types of fibre, which are kenaf, pineapple and sugar palm fibre reinforced with polylactic acid (PLA). Apart from that, the objectives of this study are to study the compression behaviour, the scaling effect and the finite element analysis of the sandwich square honeycomb structure. Furthermore, this research also investigates the effect of recycling the natural fibre composite in term of its strength and energy absorption values. This study was conducted on natural fibre composites made from mixing PLA with three different types of natural fibres; kenaf, sugar palm and pineapple leave fibres. The long fibres were crushed and sieved into short fibres to ensure uniformity throughout the process including recycling. Then fibres and PLA were mixed using a batch mixer at 180°C before being crushed into small pellets for the hot press moulding. Hot pressing the pellets in a designated mould for 5 minutes at 180 ° C and 60 tonnes of pressure produced plates of each fibre with a thickness of 3 mm. Later on, the plate underwent tensile test and the sandwich square honeycomb structure fabricated from the plate underwent a compression test. The end products were then recycled into plates by the same process of crushing into pellets, hot pressing and fabrication into sandwich square honeycomb structure without adding any new materials. The recycled sandwich square honeycomb were also put through the same set of tensile and compression test in order to investigate the strength and energy absorption capabilities. Tensile strength of kenaf/PLA composite recorded the highest value of 36.28 MPa for new composite and 19.72 MPa for recycled composite. After the recycling process, the tensile strength exhibit a reduction between 5-45 %. The Poisson's ratio of the composite both new and recycled was also recorded between 0.2-0.3, which is the normal range for natural fibre composites. Besides that, in term of scaling factor, the value of compression stress and energy absorption increased when the number of cell increased. The sugar palm/PLA indicated the highest increment of 115.20% when the number of slots doubled. Meanwhile, FE model was developed and analysed using ABAQUS 6.13 software to verify the experimental results obtained. However, when the natural fibre composite was recycled, kenaf/PLA recycled composite recorded the highest maximum stress of 7.8 MPa and energy absorption value of 720.12 J compared to recycled pineapple/PLA and sugar palm/PLA composite. Finally, the comparison between the FE model and experimental data presented a small percentage error of 10.97 % due to the geometries' imperfections of the experimental sandwich square honeycomb structures. This showed that the recycled natural fibre composite has a good possibility to be used to replace current materials in low load bearing application especially in furniture making industry

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LIST OF SYMBOLS

σ	Tensile stress
E	Young's modulus
ε	Tensile strain
ε_x	Transverse strain
ε_y	Longitudinal strain
A_t	the cross-sectional area at the smallest part (tensile)
G	original length of the specimen
L_f	final length of the specimen
P_t	external axial load(tensile)
ν	Poisson's ratio

LIST OF ABBREVIATIONS

EDM	Electro-discharge machine
FEA	Finite element analysis
FE	Finite element
HDPE	High density polyethylene
HIPS	High impact polystyrene
LDPE	Low density polyethylene
Ni-Cr	Nickel-Chromium
Ni-Cr-P	Nickel-Chromium-Phosphorous
PALF	Pineapple leaf fibre
PET	Polyethylene terephthalate
PLA	Polylactic acid
POM	Polyoxymethylene
PP	Polypropylene
SPF	Sugar palm fibre
SPF/SPS	Sugar palm reinforced plasticized sugar palm starch
SSHS	Sandwich square honeycomb structure

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